

## APPENDIX 1: POSTER SESSION ABSTRACTS

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### **Response of the P450 RGS Assay to Extracts of Sediments Collected From Puget Sound, WA**

**Jack W. Anderson and Jennifer M. Jones**

*Columbia Analytical Services*

**Edward Long and Jawed Hameedi**

*National Oceanic and Atmospheric Administration*

The induction of the cytochrome P450 gene family, specifically CYP1A1, in response to toxic and/or carcinogenic organic compounds is widely used as a biomarker for exposure to contaminants in the aquatic environment. Organic compounds, including dioxins, furans, coplanar PCBs, and high molecular weight PAHs, are known to bind to an intracellular cytosolic protein referred to as the aryl hydrocarbon (Ah) receptor. This complex is translocated to the nucleus of the cell, where it interacts with xenobiotic response elements in the promoter of the CYP1A1 gene and causes transcription of the P450 enzyme system. CYP1A1 induction has been used in the development of toxic equivalency factors (TEFs) for polychlorinated dibenzo-dioxins (PCDDs), polychlorinated dibenzo-furans (PCDFs), and PCB congeners as a measure of their potency relative to 2,3,7,8-tetrachlorodibenzo-p-dioxin (Safe 1994). Similarly, TEFs have been developed for PAHs as a measure of carcinogenic potential compared to B[a]P (U.S. EPA 1993).

The P450 Reporter Gene System (RGS) measures induction of the CYP1A1 protein via the reporter gene, firefly luciferase, to determine the presence of inducing compounds in environmental samples. As such, RGS gives an actual assessment of the potential of contaminants on sediments at a specific site to produce chronic and/or carcinogenic effects of flatfish if they were to occupy the site. It also gives an indication of the chronic effects on benthic organisms at the site, as an RGS response above 60 g of benzo[a]pyrene equivalents per g was highly correlated with degradation of infaunal communities. This testing program was designed to determine the potential toxicity and carcinogenicity of sediments collected from Puget Sound, Washington. The results of this project illustrate the ability of P450 RGS to identify, rapidly and inexpensively, the most toxic and hazardous samples within a harbor, bay, or coastal section. Using the entire data set ( $n = 100$ ), 11 sediment samples were identified as containing concentrations significantly greater than the mean B[a]PEq, using the 99% confidence interval. When Everett Harbor is considered a point source of contamination within the Sound, 15 samples from that area were excluded and an additional statistical analysis of this data set ( $n = 85$ ) identified 21 samples as significantly greater than the mean. A strong correlation ( $r^2 = 0.91$ ) between the RGS B[a]PEq and the distance from a station in Inner Everett Harbor was observed.

### **The Widespread Occurrence of Elevated Summer Stream Temperatures in Upper Hood Canal Watersheds and Relation to Riparian Land Uses**

**Peter Bahls**

*Port Gamble S'Klallam Tribe*

The objectives of this study was to assess summer stream temperatures in upper Hood Canal watersheds in relation to state water quality standards and associated riparian land uses. Twenty nine max/min thermometers, placed in 20 streams, were checked weekly during the summers of 1992,

1993, and 1994. Based on preliminary findings, more intensive sampling on three streams was conducted in 1995 and 1996 using continuous reading thermometers. Results show that 14 of the 29 stations sampled between 1992 and 1994 were in violation of state water quality standards. An analysis of stream temperature in relation to riparian condition indicated that loss of forested riparian zones through agricultural use was the primary cause of elevated temperatures.

## **Real-time Monitoring of Bluff Stability at Woodway, Washington**

***Rex L. Baum, Edwin L. Harp, Richard G. Lahusen, William J. Likos, and Philip S. Powers***

*U.S. Geological Survey*

Damaging landslides occur almost every year on steep bluffs near Puget Sound. Most occur during or after periods of heavy rainfall. Previous workers have attributed such slides, particularly the deep ones, to groundwater seepage within the bluffs. Few actual measurements have been made, however, to study the relationships between rainfall, seepage, and bluff stability. During the summer of 1997, the U.S. Geological Survey began a project to monitor rainfall, groundwater pressures, and slope movement at an unstable bluff adjacent to the head of a slide that derailed a freight train during January 1997. The site is in Woodway, Washington, about 10 km north of Seattle. The monitoring project will help clarify the time lag between rainfall events and resultant water-pressure changes, the magnitude of seasonal and short-term water-pressure variations, and the effects of water pressure changes on bluff stability. Field data are collected every 15 minutes and relayed by phone to a computer network where they are processed and then presented on the World Wide Web. Near-real-time monitoring of the site will also allow us to test and refine technology that might be used for landslide forecasting, emergency notification, or mitigation.

## **Puget Sound Intertidal Habitat Inventory: Shoreline Characteristics Mapping**

***Betty E. Bookheim and Helen Berry***

*Washington Department of Natural Resources*

Accurate information on the quality, quantity, and distribution of intertidal habitats is important to monitoring and sustaining the health of Puget Sound. As part of the Puget Sound Ambient Monitoring Program (PSAMP), the Nearshore Habitat Program (NHP) in the Aquatic Resources Division of the Washington State Department of Natural Resources (DNR) inventories intertidal habitats in Puget Sound.

Intertidal habitats are characterized by interacting physical, chemical, and biological factors. The data collected by NHP focuses on two components of intertidal habitat: vegetation types and shoreline characteristics. This poster summarizes information and methods used to survey the shoreline characteristics component of our inventory. The physical attributes described in this method are derived from "A Marine and Estuarine Habitat Classification System for Washington State" (Dethier, 1990) and includes information on system, subsystem, wave or current energy, substrate, and water regime. The mapping methods used ground data in conjunction with photo-interpretation of color infrared aerial photos.

Final delineations were completed on 1:12,000 scale DNR orthophoto maps using a Zoom Transfer Scope and then digitized.

Inventory results are available in digital GIS format or paper maps. This information is being used in conjunction with our DNR intertidal vegetation inventory layer and other habitat information for management, land-use planning, and research.

## **The Regional Geologic Framework of Puget Sound, and its Application to Geologic Hazards**

***Derek B. Booth and David R. Montgomery***

*University of Washington*

***Kathy Goetz Troost***

*Shannon & Wilson, Inc., and University of Washington*

Understanding of the geologic framework of the Puget Lowland has been hampered by intrinsically complex stratigraphic relationships, obscured by dense vegetation, and confounded by outdated human comprehension of Quaternary history. These problems are nowhere better expressed than in the Seattle-Tacoma area, where the distribution and sequence of glacial and nonglacial deposits have been debated by geologists for decades. We are particularly interested in the application of geologic mapping to determining the continuity of aquitards, revealing the structural deformation that expresses the region's active tectonism, and predicting geologic hazards associated with slope instability. While developing a basic geologic framework, we are also utilizing radiocarbon dating, paleomagnetic studies, and tephrochronology to determine the distribution of, and to establish a regionally based chronology for, the deformation of critical Quaternary deposits. We are working most closely with the U. S. Geological Survey, but because of a long history of public and private geologic studies in this area we are emphasizing a broadly collaborative effort. When integrated with geophysical models of the Earth's crust beneath Puget Sound, this geologic framework can validate predictions of large-scale tectonic deformation expressed by the region's high seismicity. When added to a simple slope-area model that already can credibly predict the location of many observed landslides, this framework should permit a much better understanding and anticipation of catastrophic hill-slope failures.

## **Identification and Delineation of Deposits from Log Handling and Pulping Operations Using Sediment Profile Imaging**

***David G. Browning and Gene Revelas***

*Striplin Environmental Associates*

Organic particulate deposits associated with log handling, log storage, and pulp-mill discharges in marine and fresh waters have recently come under increased regulatory scrutiny. A first order evaluation is determining the horizontal and vertical extent of these deposits. A method has been developed whereby wood debris/fiber volume estimations are made by comparing the amount of wood and fiber particles in sediment profile images (SPI) images to petrographic modal estimators. Volumetric estimates can be determined for the top 10 cm of the sediment column or the entire depth of the sediment column represented in the SPI image. Where optical contrast between wood debris and the sediment column is high, particles as small as 0.5 cm can be identified. This technique has been used to delineate and estimate the percentages of debris in the sediment column associated with log rafting and storage in Commencement Bay and Lake Washington, WA in addition to characterizing a pulp effluent deposit in a southeast Alaska fjord. In each study area, differences in wood/pulp debris morphology and sedimentary fabric were observed. Areas containing the greatest amounts of wood debris exhibited the shallowest apparent redox potential discontinuity (RPD) depths in each study. Shallow RPD depths, coupled with highly reduced underlying sediments, are indicative of organic loading and high sediment oxygen demand. RPDs generally deepened away from the areas containing discernible wood/pulp debris. The identification

and estimation of amounts of wood debris using SPI provides a primary measure of wood debris/pulp deposit extent, whereas the distribution of the RPD depths provide a secondary measure of the degree of sediment organic loading where distinct wood particles can no longer be seen.

## **Monitoring Non-Point Source Pollution in an Agricultural Watershed: Water Quality in an Estuarine Slough, Padilla Bay, Washington**

***Douglas A. Bulthuis and Robin M. Cottrell***

*Padilla Bay National Estuarine Research Reserve*

Padilla Bay National Estuarine Research Reserve monitors water quality in Padilla Bay and its tributaries as part of the National Estuarine Research Reserve System-Wide Monitoring Program. Joe Leary Slough, the largest freshwater tributary to Padilla Bay, drains a predominately agricultural watershed that includes orchards, berries, beef grazing, dairies, and annual crop agriculture. Salinity, temperature, dissolved oxygen, turbidity, and pH were measured at 30-minute intervals for more than one year at the mouth of Joe Leary Slough. The data indicate tidal influence, seasonal differences, storm event responses, and the effects of agricultural practices.

## **Shellfish Farm on Hood Canal**

***Colleen A. Burge, Amalia C. Baker, John Pitts and Charles Baker***

*Quilcene High School*

The Quilcene-Brinnon Schools Shellfish Science Club is an educational, high school club that raises oysters and teaches the community about water quality. The oysters are raised on both Quilcene and Dabob bays off the Hood Canal. 4.7 acres of beach were donated by Jefferson County and the Washington Department of Fisheries and Wildlife. The oysters raised are sold at fairs, festivals and an annual community dinner. At these functions, water-quality brochures are handed out to stress the importance of clean water to the community.

Student members have a variety of educational activities for participation, from business procedures to labor intensive work. The club's main goal is to raise enough money to take a fun and educational, aquaculture-related field trip every two years.

Quilcene High School students have managed and operated the model farm for over three years, receiving two environmental awards, one locally and one nationally. The club hopes to continue to raise oysters and teach the community about the importance of water quality.

## **Application of Regional Tribal Fish Consumption Study Data to Risk Assessments for Local Sites**

***Christine M. Chew and Nancy A. Musgrove***

*Roy F. Weston, Inc*

Because fish consumption behaviors vary widely among different populations, site-specific exposure data and application of those data are critical to ensure realistic estimates of exposures and resulting potential risks. A recent study of fish consumption habits of two Puget Sound Native American tribes provides substantial information on both the fish harvesting and fish consumption patterns of tribal members. This study provides consumption rates for all fish and for functional groups of finfish and shellfish, as well as information such as preparation methods, harvesting areas,

and parts of the fish consumed. Because these data may serve as surrogates for other Puget Sound tribal or subsistence populations, direct application of values reported in the study may not provide reasonable estimates for the different exposed populations. Site- and population-specific exposure issues must be addressed. For example, types of finfish and shellfish harvested, the harvestable amount of these fish available at the site, and the portion of consumed fish harvested from the site affect how these data can best be applied to risk assessment calculations. Where possible, fractional use of averaged data may provide more accurate surrogate values than unmodified data. In addition, further examination of the data used in the fish consumption study has yielded a more specific breakdown of exposure patterns with particular regard to different types of shellfish.

## **An Indicator Study of the Environmental Health of the Sequelitchew Creek Watershed**

*Emily E. Cudney, Jessica J. Fox, Kris M. Grinnell, Ryan W. Smedes, and Kirsten C. Workman*

*Pacific Lutheran University*

Sequelitchew Creek flows three miles from Sequelitchew Lake on Fort Lewis, through the City of DuPont, into the southern portion of Puget Sound. The watershed is small, but on the verge of rapid development as a planned community that includes residential, commercial, and industrial land use. The community wants to maintain a small community feeling and a healthy creek system as this development occurs.

As part of a class on Environmental Methods of Investigation at Pacific Lutheran University, we collected geological, chemical and biological field data from the stream as well as assembling land use, economic, demographic, and political data about the entire watershed. We used these data to develop a preliminary indicator study of the environmental health of the Sequelitchew Creek watershed. We identified key issues that the watershed faces and selected indicators to be monitored over time. These indicators include measures of the creek's properties: discharge, total phosphate, and fecal coliform. These indicators also include as characteristics of the watershed: percent of residents who work in DuPont, types of businesses, road sizes, and acres of open space. For each we identified an optimum value and made specific recommendations to help the community improve the environmental health of the watershed.

## **Flow Estimation Model for Small to Medium-Sized Streams in Puget Sound Based on Sparse Measurements and Precipitation Data**

*Matthew Davis and Chris Cleveland*

*Brown and Caldwell*

Flow histories of surface-water discharge are an essential piece of information in many studies; however, dedicated flow monitoring can be expensive and difficult to maintain. Hydrologic models have been used with success to estimate flows when measurements are not readily available. Some models however are data intensive, requiring information on soil types and properties. Quantification of these parameters can be expensive and time consuming. A model has been developed to predict stream flows using easily attained measurements: daily precipitation data and intermittent stream flow measurements. The model routes precipitation through a series of "boxes" that idealize different storage and transfer processes within a watershed. Model calibration adjusts the parameters that control flux into and out of the boxes. Intermittent streamflow measurements are used to guide the calibration process and evaluate

error. Optimization of the model parameters may be accomplished through trial and error or automated with an optimization technique such as a genetic algorithm. The model is simple enough to be used in a spreadsheet or may be coded in a more robust form in a -alone application. The model is well suited for streams draining small to medium-sized watersheds and was applied successfully in the Budd Inlet Intensive Study to nine streams.

## **Nutrient Transport from Major Rivers to Puget Sound and Adjacent Waters**

***S.S. Embrey and E.L. Inkpen***

*U.S. Geological Survey*

Historical data were compiled for the Puget Sound Basin study unit of the U.S. Geological Survey's National Water Quality Assessment Program to calculate nutrient loads transported each year from major watersheds to Puget Sound and adjacent waters. Major nutrient source loadings also were estimated to relate land use with watershed nutrient yields. With data from 24 water-quality monitoring sites, a computer program calculated average annual nitrogen and phosphorus loads for 1980–93.

Each year, rivers and streams transport 11,000 tons of inorganic nitrogen, 9,900 tons of organic nitrogen, and 2,100 tons of total phosphorus to Puget Sound and adjacent waters. Because of their large stream flows, the Skagit and Snohomish Rivers carry the largest nutrient loads. Nutrient yields per square mile of drainage basin, however, tend to reflect land use and development. The populous, agriculturally developed watersheds in the eastern half of Puget Sound Basin generally yield more nutrients than the less developed basins of the Olympic Peninsula. Yields up to 2.8 tons of nitrogen per square mile from the Samish and Nooksack River Basins correspond to source loadings of 9–10 tons of nitrogen per square mile from fertilizer, animal manures, and atmospheric deposition.

## **Marine Recreational Fisheries Statistical Survey (MRFSS)**

***Pamela Erstad, Lori Takeoka, Sue Hoffmann***

*Washington Department of Fish and Wildlife*

The Marine Recreational Fisheries Statistical Survey (MRFSS) program began in Washington State in 1979 through 1988 and recently began again in 1996. It is funded by the Pacific States Marine Fisheries Commission (PSMFC) and its purpose is to collect catch-and-effort information from marine recreational anglers along the west coast of the U.S. This information is very useful to recreational bottomfish managers because Washington state currently has no effective methodology for assessing recreational bottomfish harvests in Puget Sound. There are two components of the survey: an intercept survey that collects information on species composition and CPUE, and a follow-up telephone survey which is used to estimate total effort. In addition, information is being collected on bycatch, an issue that is becoming an increasingly important element of fishery management. Finally, the MRFSS Program collects economic information on what anglers are willing to spend on recreational fishing in Washington State. This data is extremely important because it provides information for resource managers, legislative bodies, and sportfishing organizations on the economic contributions of sport fishing. This in turn could help fund special projects with the aim of enhancing recreational fishing throughout the state.

## **The Importance of Combined Sewer Overflow Water-Quality Characterization in Bremerton's Combined Sewer Overflow Reduction Plan**

***Melinda J. Fohn and Kathleen Cahall***

*City of Bremerton Public Works and Utilities*

With funds from a Washington State Centennial Clean Water Fund Grant, the City of Bremerton conducted two years of intensive water-quality monitoring of its combined sewer overflow (CSO) discharges. Flow-weighted composite and grab samples from 15 CSO sites were obtained and analyzed for typical parameters, including nutrients, metals, and organics. Results were compared to marine acute water-quality criteria and other nonpoint sources.

Discharge from a combined sewer system is composed of wastewater and storm water. The average wastewater component for each CSO site was determined. The concentration of ammonia and nitrates in the combined sewer sample was compared to an ammonia value representing 100% waste water. CSO sites had a wide range of wastewater component values, ranging from 1.8% to 37.5%. The wastewater pollutant loading for each CSO site into the receiving waters was determined using 1996 flow volume and percent waste water. CSO site pollutant loading reveals a more complete picture of the impact to the receiving environment of the different sites when compared to evaluation of flow volume only. The City of Bremerton realizes the importance of CSO-discharge water-quality information in prioritizing and evaluating CSO reduction projects.

## **Water Quality Goals for Lake Sammamish Derived from a Long-term Monitoring Program**

***Jonathan Frodge and Joanna Richey***

*King County Water and Land Resources Division*

Diversion of sewage from Lake Sammamish in 1968 reduced the external load of phosphorus by about 35%. Lake Sammamish responded favorably to this nutrient diversion. Over a 5–10-year period, total phosphorus concentrations decreased from approximately 30–35 mg/liter to 15–20 mg/liter. During this period of lake recovery, summer concentrations of chlorophyll decreased from 3–4 mg/liter to about 1–2 mg/liter, with a corresponding increase in water clarity from about 3.3 meters to 4.5 meters.

These water quality gains are currently being reduced by increased nonpoint pollution from continuing development of the watershed. Since 1978 total phosphorus concentrations have increased from about 13 mg/liter (1978) to 22 mg/liter. Empirically derived water quality goals of 22 mg/liter volume weighted total phosphorus are expected to maintain average summer algae populations at current levels (2.8 mg/liter chlorophyll a), and should result in summer average water clarity of about 4.0 meters. If these water quality goals are maintained, beneficial uses in Lake Sammamish and downstream water quality in the Sammamish River will be protected. These water quality goals provide both a public education tool and a basis for the adaptive management of this watershed.

## **Production and Abundance of Heterotrophic Bacteria in Budd Inlet (WA) During Spring and Summer of 1997, and their Distribution Relative to Effluent from a Wastewater Treatment Facility**

***James Gutholm and Gerardo Chin-Leo***

*The Evergreen State College*

Bacteria in the water column can be important contributors to the eutrophication of estuaries. We measured bacterial abundance (DAPI) and production ( $[^3\text{H}]$ -Leucine) in Budd Inlet (WA) during spring and summer of 1997. This estuary is the southernmost inlet in Puget Sound and may be especially susceptible to eutrophication because of restricted tidal flushing. It also receives substantial nutrient inputs from the Deschutes River and from the wastewater treatment facility (LOTT) that services a large urban area. In spring, bacterial abundance ranged from  $11.01 \times 10^6$  cells/mL to  $3.85 \times 10^6$  cells/mL, and bacterial production from  $18.37 \mu\text{g C/L/day}$  to  $4.73 \mu\text{g C/L/day}$ . These values are in the high range compared to other productive estuaries. To examine the possible enhancement of bacterial activity by wastewater, sampling stations included the area where treated waste water enters the bay. In spring, both bacterial abundance and production were significantly higher near the sewage outfall than at a site (Boston Harbor) 10 km away ( $p > 0.01$ ). In summer, we increased the number of sampling stations near the LOTT outfall. During this period, even though both bacterial abundance and production were higher than in spring, no obvious trends were found with increasing distance away from LOTT.

## **Viral Hemorrhagic Septicemia Virus in Herring from the Puget Sound Spawn-On-Kelp Fishery**

***Paul Hershberger and Richard Kocan***

*University of Washington*

*Objective:* To determine whether activities involved with closed pound spawn-on-kelp (SOK) fisheries contribute to active infections of viral hemorrhagic septicemia virus (VHSV) in associated herring.

### *Methodology:*

- Phase 1: Wild herring from an SOK pound were sampled prior to impoundment and after 24 hr of confinement within the pound.
- Phase 2: Sexually mature herring were purse seined, transported to a net pen, and sampled from within the pen at 48-hr intervals. Tissues from all sampled fish were analyzed for VHSV via plaque assay.

### *Results:*

- Phase 1: None of the herring (0/30) tested VHSV+ prior to introduction to the pound, while 12.2% (5/41) tested VHSV+ after 24 hr of confinement.
- Phase 2: None of the herring (0/100) tested VHSV+ upon introduction to the net pen but the percentage of VHSV+ herring increased to 17% (17/100) after eight days of confinement.

*Conclusions:* Activities associated with closed pound SOK fisheries are responsible for transfer and/or activation of VHSV infections among impounded herring. VHSV+ herring resulting from SOK activities may spread viral infections to wild fish due to:



1. The proximity of wild herring to the pounds, and
2. Release of VHSV+ post-spawn herring from the pounds.

## **Bull Kelp's Parasitic Brown Algae**

***Bruce Higgins***

*Marine Concepts*

Typical methods for bull kelp (*Nereocystis luetkeana*) distribution and condition estimation may be missing health issues. It was reported in the 1970s that bull kelp can be infected by a parasitic brown alga. This parasitic condition can manifest itself in a variety of ways, but one that is obvious by visual exam is a warty external appearance. It may not have been widespread in the past, but has moved from rare or unusual to common at Edmonds Underwater Park, which adjoins a many acre kelp forest. Prior to 1992, this condition was rare, but starting with the 1993 season, native kelp and rafted kelp shows consistent evidence of this problem.

The condition appears to begin by a 5-cm stipe length and continues to persist throughout the life of the plant. It does not appear to influence the development of the blades or reproduction later in the season. It also does not appear to be stationary in space as kelp noted with the problem in one site does not appear to have maintained the condition the following year. This is a factor that may need to be included in future kelp census studies.

## **Island County/WSU Beach Watchers' Volunteer Intertidal Monitoring Program**

***Jan Holmes, Susan King and Mary Farmer***

*Island County/WSU Beach Watcher Volunteers*

Island County/WSU Beach Watchers are trained volunteers dedicated to protecting and preserving the fragile environment of Island County and Puget Sound waters through education and public awareness. The goal of the WSU Beach Watchers' Monitoring Program is to document in an accurate and meaningful manner the ongoing changes in beach profiles and biodiversity at specified beach sites following beach-monitoring guidelines.

The WSU Beach Watchers' program provides citizens an excellent opportunity to learn more about Island County beaches—about the plants and animals that live on a healthy beach and about the factors that might cause changes on a beach, either suddenly, or more slowly over time. Beginning in 1990, WSU Beach Watcher volunteer monitors have documented beach profiles and surveyed the numbers of plants and animals in the intertidal zone. The procedures have been field tested, standardized and streamlined until all volunteers, regardless of backgrounds, are able to understand and follow the guidelines after their initial training. The same monitoring procedures are applied to all types of beaches. The product, over time, is an expanding, quality controlled, baseline study of our island's beaches with data invaluable for the assessment of the health of our changing shores. The results of the development of the WSU Beach Watchers' beach monitoring program are currently being published as a Volunteer Monitoring Training Manual, including sections on Watershed Monitoring and Volunteer Training and Support. This manual will be shared with other environmental programs interested in developing volunteer intertidal monitoring programs in Puget Sound and beyond.

## **Ecological Functions of a Saltmarsh/Mudflat Complex Created Using Dredged Material at Jetty Island, Washington—The Final Verdict.**

***Jonathan P. Houghton***

*Pentec Environmental, Inc*

***R. H. Gilmour and D. L. Gregoire***

*Port of Everett*

The Port of Everett and US Army Corps of Engineers constructed a 15-acre berm using clean dredged sand to form a protected 19-acre mudflat. Four objectives were established for testing project success: 1) to balance erosion losses on the island, 2) to create additional dune grass habitat, 3) to create a protected embayment that would be colonized by marine invertebrates, and 4) to demonstrate a beneficial use of dredged material. Productivity and invertebrate biomass were expected to increase in the protected embayment, improving habitat for fish, shorebirds, and waterfowl.

Plantings of *Jaumea*, *Salicornia*, and *Distichlis* in 1991 flourished and achieved over 100% cover in some areas by 1993. Epibenthic zooplankton sampling in spring 1992 and 1994 showed higher abundances of juvenile salmonid prey species inside the berm than at comparable elevations on exposed shorelines along the remainder of the island. Beach seining in 1992 and 1994 demonstrated that juvenile salmon and other fish, especially juvenile surf smelt, use the embayment during high tides. The mudflat is intensively used by migrating shorebirds and bald eagles. Data from 1995 sampling demonstrated that the project met all pre-established criteria for success. Additional nourishment of the berm is planned in 1998 to maintain its physical integrity and preserve the ecological benefits.

## **Seismic Landslides in Puget Sound (SLIPS): Quaternary Faulting and Submarine Mass-Wasting**

***Robert E Karlin and R. J. Watters***

*University of Nevada*

***Mark L Holmes***

*University of Washington*

Structure, stratigraphy, and geometry of Quaternary submarine landslides have been mapped from Everett to Tacoma using seismic profiling and side-scan sonar imaging. Massive submarine landslide complexes (>1 km wide) occur in several locations including Maury Island near Tacoma, Skiff Point (Bainbridge Island), Alki Point in West Seattle, Possession Point (Whidbey Island), Mukilteo, Edgewater, and Gedney Island near Everett. Ages of these slides are being determined by dating turbidite layers in piston cores. Submarine landslides are relatively common in the eastern passages of Puget Sound and tend to be better preserved than on land. Conversely, despite numerous coastal slides, western passages generally do not have submarine expression of mass wasting because of intense tidal scouring of the submarine slopes. Older Pleistocene units north of Seattle tend to fail as coherent blocks, whereas younger Esperance Sand/Lawton Clay units south of Seattle generally fail as incoherent slides, flows, and spreads. Many large slides in or near major fault zones appear to have been activated several times during the Holocene. Extensive Holocene thrust faulting and large landslides associated with the South Whidbey Island fault zone suggest that this area is tectonically active and may constitute a major seismic risk to the Everett-north Seattle area.

## Geophysical Investigation of the Pacific Sound Resources and Eagle Harbor SuperFund Sites, Puget Sound, Washington

**Robert E. Kayen, Terry R. Bruns, Michael D. Fisher, Michael R. Hamer, and Homa Lee**  
U.S. Geological Survey

**Chris Beaverson**  
NOAA Hazmat

The US Geological Survey, EPA, and NOAA acquired side-scan sonar, seismic reflection profiles, and bathymetry over the Eagle Harbor and Pacific Sound Resources SuperFund sites. Our objective was to spatially map units of potentially contaminated sediment placed offshore during operations at these sites. Our principal tool to acquire seafloor imagery was the Datasonics SIS-1000, a single deployable device with three channels supporting CHIRP side-scanning sonar and a downward-looking CHIRP sub-bottom profiler. Single-beam bathymetric surveys were conducted by the Hydrographic Section of NOAA to augment the geophysical dataset collected by the USGS.

Our investigation focused on addressing the following concerns: (1) determine the areal extent, thickness, and orientation of any potentially contaminated sedimentary layers; (2) ascertain any unusual characteristics or anomalies associated with the sediment surface or sub-bottom layers; (3) determine potential NAPL pathways associated with anthropogenic layers; (4) determine the extent of submarine structures. At Eagle Harbor, we additionally sought to characterize the morphology and spatial extent of the cap material placed on the harbor floor. For both sites, we found that the side-scan imagery, coupled with bathymetry, allowed for detailed description of the surface morphology of the sites, whereas, patchy zones of bubble-phase gas in the sediment-column hindered our efforts to observe the sub-seafloor stratigraphy in seismic reflection profiles.

## *Ichthyophonus* Infections in Wild and Lab-Reared Pacific Herring (*Clupea pallasii*)

**R. Kocan, P. Hershberger, and T. Mehl**  
University of Washington

Objectives:

- 1) Determine pathogenicity of *Ichthyophonus* for herring; and
- 2) Describe the natural history of *Ichthyophonus* in wild herring.

Laboratory-reared herring infected with *Ichthyophonus* spores began dying in 11 days. Skin lesions were detectable by 36 days, and by 56 days, 90% were dead. *Ichthyophonus* was cultured from all infected tissues. Infected tissues were injected into coast range sculpins (*Cottus aleuticus*), which became infected and/or died. Sculpins fed infected tissues became infected, while the controls did not.

Wild herring demonstrated skin lesions in 6%, 5%, and 4% of 0-year, 1+, and 2+ fish, respectively, while 6%, 23%, and 52% of each group cultured positive for tissue-associated *Ichthyophonus*. There was no difference in weight or length between infected and uninfected fish.

**Conclusions:** *Ichthyophonus* is pathogenic for nonimmune herring, causing nearly 100% mortality. Lesions of the heart, liver, spleen, muscle preceded the appearance of skin lesions. Tissue culture appeared to be the most efficient method for detecting this organism.

Six percent of wild herring were naturally infected by 3–4 months old, while 52% of adults were infected. There was no evidence that the health or survival of wild fish were affected, but

different environmental conditions or levels of infection could result in a significant level of morbidity and mortality.

## **Puyallup River Radio-Telemetry Study: White River Spring Chinook, 1996–1997**

***Russ Ladley, Blake Smith, Michael MacDonald, and Travis Nelson***

*Puyallup Tribal Fisheries*

Chinook salmon, *Oncorhynchus tshawytscha*, with esophageally implanted radio tags were tracked in the Puyallup River system to determine movement patterns, migration hazards and spawning locations. A total of 272 adult chinook were tagged comprising 12% and 17% of the adult escapement above Mud Mountain Dam in 1996 and 1997, respectively. White River chinook were targeted by tagging fish at the Buckley trap located on the White River and those fish demonstrating early freshwater entry into the lower Puyallup River. Entry timing of White River stocks and summer/fall run hatchery stocks overlapped by six weeks. Movement, holding periods and holding locations varied widely among individual fish. The single greatest travel rate recorded was 32.5 km in 24 hours. The majority (75.5%) of the fish tagged moved through the lower Puyallup River (< rkm 17.3) within 14 days. Holding periods ranged up to 10 weeks. Males exhibited a higher propensity to move upstream and then back down. Most (74% of all redds) spawning took place within two non-glacial tributaries, but ranged from river km 18 to 89.8 of the mainstem White River. Redd elevations ranged from 45 to 853 m above sea level. Spawning occurred earlier within high-elevation stream reaches than in low-elevation reaches.

## **Development of Arsenic Speciation Data for Edible Biota, Sediments, and Water**

***Roseanne M. Lorenzana***

*USEPA, Region 10*

A collaborative research project between USEPA Region 10 (Seattle) and the USEPA National Exposure Research Laboratory (Cincinnati) was started in September 1997. The objectives are (1) to develop a laboratory extraction method(s) for speciated arsenic in fish, shellfish and seaweeds which can be used with existing analytical arsenic detection methodologies; (2) in Alaska and Puget Sound samplesto determine concentrations and relative proportions of dimethylarsentate (DMA), monomethylarsonate (MMA), inorganic arsenic and organic arsenic and (3) to determine the effect of typical preparation and cooking procedures on speciated arsenic concentrations. The technical approach involves further developing analytical methodologies, collection of Puget Sound fish, shellfish, seaweed, water and sediments, analyzing the samples, and publishing an exposure assessment utilizing information from Puget Sound seafood consumption surveys (completed in 1996 (tribal) and 1997 (Asian Pacific American)). The expected outcomes include a standard operating procedure for assessment and validation of the quality of arsenic speciation data, publication documenting an extraction and analytical laboratory method, and publication of findings and a database which provides results of analyses in a manner that can be used in regional risk assessments.

## **Contaminant Monitoring of Surf Scoters near Tacoma, Washington as part of the Puget Sound Ambient Monitoring Program**

**Mary Mahaffy and Jeff Krausmann**

*U.S. Fish and Wildlife Service*

**Dave Nysewander**

*Washington Department of Fish and Wildlife*

Adult male surf scoters were collected in Puget Sound near Tacoma, Washington in October 1995 and February 1996. Surf scoters are a relatively abundant winter resident seaduck in Puget Sound. Comparing the contaminant concentrations in scoters collected after they first arrive to those collected in the late winter allows an evaluation of contaminant exposure during the winter. Concentrations of mercury and chromium increased slightly in wintering scoters; however, they were well below concentrations known to cause negative impacts to birds. No appreciable uptake of polyaromatic hydrocarbons by the scoters was observed during their winter residency. General bird health was evaluated by examining a variety of tissue samples for lesions and conducting blood cell counts and serum chemistry. In general, the surf scoters collected appeared to be in good condition. The scoters were primarily feeding on mussels, clams, tube worms, and snails.

## **Association of Smallmouth Bass (*Micropterus Dolomieu*) Nests with Residential Piers in Lake Sammamish, King County, Washington**

**Roderick W.R. Malcom**

*Muckleshoot Indian Tribe*

Freshwater piers may create habitat for predators of juvenile salmon or increase the interaction between salmon and their predators. Increased predation upon juvenile salmon may impair restoration efforts. To ascertain the potential for piers to increase the interaction between juvenile salmon and smallmouth bass, an introduced predator, 2.2 km of Lake Sammamish was surveyed by boat. Bass nests were located and the distance to the artificial inwater structure measured. Nearshore salmon use was determined by the spot beach seining and through analysis of other salmon use data collected in Lakes Washington and Sammamish. Smallmouth bass nests were preferentially associated with artificial in-water structure. Fifty percent of smallmouth bass nests were located within 2 meters of artificial in-water structure and 75% of nests within 11.5 m.

Though this study did not attempt to determine if smallmouth bass spawning is limited by lack of in-water structure, it did demonstrate residential piers and other artificial in-water structure provide focus for smallmouth bass spawning. Given the existing number of piers and ongoing construction rates, future research should quantify the impacts of piers upon the smallmouth bass population in Lake Sammamish and explore the association of other predators of juvenile salmon with artificial in-water structure.

## **Characterization of Groundwater Discharge into a Tidally Influenced Surface Water Body, Thea Foss Waterway, Tacoma, Washington**

***Daniel W. Matthews***

*Hart Crowser, Inc.*

This talk discusses our methodology and presents preliminary results of our evaluation of groundwater discharge rates and associated chemical mass-loading rates into the tidally influenced Thea Foss Waterway. Because the Thea Foss Waterway is known to be a groundwater discharge area, mobilization of contaminants by flowing groundwater needs to be considered in evaluation of alternatives for remediation of contaminated sediments. The field program for the project included installing and sampling monitoring wells within and adjacent to the waterway, sampling recent marine sediments in the waterway, analyzing chemical partitioning between sediment and groundwater, sampling groundwater discharging to the waterway by means of well points and bottom flux chambers, monitoring water levels during a tidal cycle, evaluating groundwater salinity, and aquifer testing. The fate and transport of man-made contaminants dissolved in groundwater and adsorbed to sediments was estimated by several methods including numerical modeling techniques.

## **Environmental Limitations to Vegetation Establishment and Growth in Biofiltration Swales**

***Greg Mazer***

*University of Washington*

To combat nonpoint source water pollution, federal and local governmental agencies throughout the country have required construction of “in pipe” stormwater quality improvement facilities. One such facility, the biofiltration swale (also called bioswale or biofilter), is an open channel possessing a dense cover of grasses and/or wetland plants through which runoff is directed during storm events. Aboveground plant parts (stems, leaves, and stolons) physically filter particulates and their associated pollutants as runoff passes slowly through the channel. Herbaceous cover is considered to be well correlated with treatment performance.

Environmental conditions and construction history were examined for eight biofiltration swales in King County, WA to determine relative importance of and threshold values for the various factors influencing vegetation establishment and growth. To improve future biofiltration swale design and performance, more consideration to providing seeded grasses with environmental conditions conducive to germination and establishment is recommended. However, even when installed properly, bioswales may not perform as anticipated in the long term if base and storm flows become channelized and/or base flow (inundation) persists through the growing season. Therefore, I recommend restricting biofiltration swales to very low flow (discharge and velocity) conditions and constructing large retention ponds and wetlands to improve stormwater quality under high-flow conditions.

## **Geologic Mapping in the Eastern Juan de Fuca Strait**

***David.C. Mosher, Kim Conway, Robert Kung***

*Geological Survey of Canada*

***Antony Hewitt***

*University of New Brunswick*

High-resolution geophysical mapping in the eastern Strait of Juan de Fuca has led to the identification of three Quaternary geologic units: 1) till and diamict, 2) glacio-marine sediments, and 3) Holocene reworked sediments. Till is an acoustically amorphous unit and underlies most of the Strait. It is exposed at the seafloor in places, especially on the shallow banks. Glacio-marine sediments are typically layered and overlie till and outcrop over much of the seafloor. They have been extensively eroded. Holocene sediments consist of reworked glacio-marine and till material, since there is very little modern sediment input into the eastern Juan de Fuca Strait. This material is thin over much of the strait and thickens near banks, islands, and the coastline, areas where there is abundant sediment supply. This Holocene reworked material shows abundant evidence of strong current activity. Over much of the sea floor it is thin, forming a lag over older deposits, with bedforms developed on the surface. Adjacent to banks and coastlines it forms drifts and large sand waves. In one area south of Discovery Island these sandwaves are 25 m high and 500 m in width.

## **Two Years of Repetitive Side-scan Sonar Mosaics of the Point Grey Ocean Disposal Site, Vancouver, Canada**

***David.C. Mosher and Ralph G. Currie***

*Geological Survey of Canada*

***Dixie Sullivan***

*Environment Canada*

One of the most active designated ocean disposal sites on the west coast of Canada is just outside Vancouver Harbor, off Point Grey in the central Strait of Georgia. The site, defined by a circle 10.78 km<sup>2</sup> in size, was officially designated in 1968, although dumping has been occurring in the region since 1938. It is in water depths between 210 and 250 m. Approximately 9.0 million tons of material has been dumped at the site since its designation. Repetitive side-scan sonar mosaicing of the ocean floor, combined with video inspection using a remotely operated vehicle (ROV), are two monitoring tools used in this study. The intent is to investigate the impact of disposal on the sea floor, the rate of burial of disposed material, the dispersal rate of disposed material, and the amount of disposal occurring outside of the prescribed area. Digital geo-referenced mosaics allow for calculation of difference maps, which highlight newly disposed material. Approximately 85,000 m<sup>3</sup> of material were dumped during a one-month period between surveys. ROV observations show the disposed material to consist of wood-waste spoils, excavation material from construction sites, and bundle wire from saw mills.

## **Weak Osmoregulation Observed in *Cancer gracilis* (Crustacea: Brachyura) from Southern Puget Sound**

**Nicole Ann Nelson, Raphael Ritson-Williams, and Erik V. Thuesen**  
*The Evergreen State College*

Although very abundant in the Puget Sound estuary at salinities near 25 g/kg (Kozloff 1996), *Cancer gracilis* is generally considered to be a coastal species unable to tolerate estuarine salinities (Jensen 1995). In order to investigate the osmotolerance of *C. gracilis*, we maintained crabs at 15, 20, 25, and 37 g/kg for an acclimation period of two weeks. Our results show that *C. gracilis* has a 100% survival rate at salinities of 20 and 25 g/kg. Hemolymph drawn from crabs acclimated for four hours to salinities ranging from 17-34 g/kg shows *C. gracilis* to be a weak osmoregulator at salinities from 17-20 g/kg, similar to previously published reports for *C. magister*. Osmoregulation was not observed after a 24-hour acclimation period, whereby the hemolymph of all crabs was found to be isotonic with the seawater. We also investigated the enzyme carbonic anhydrase (CA) that contributes to ionic regulation. Assays were performed on gill CA activities using the DCO<sub>2</sub>/DpH-method to obtain the CA activity of each gill. No difference was found in CA activities between gill pairs, indicating that there are no specialized performance patterns in the gills of *C. gracilis*.

## **Long-Term Patterns of Resident Orca Occurrence in Relation to Salmon in Puget Sound and the San Juan Islands**

**Richard W. Osborne**  
*The Whale Museum*

The diet of the resident orcas that frequent the inland marine waters of Washington State and southern British Columbia has been shown to be dominated by a preference for salmon. The loss and/or severe reduction in salmon resources would be expected to correlate with changes in the pattern of occurrence of these orcas in the area. The year-round monthly occurrence of these orcas has been documented by pooling observations collected from public and private sighting networks in place in Washington and British Columbia since 1976 (N= 15,957). The most recent 15 years of this information has been coded as the number of days per month that resident orcas have been detected. Annual patterns of change were then assessed by month and compared with a) Washington State monthly salmon sport catch records, b) Fraser River sockeye and pink salmon run estimates, and c) for an overall trend that might indicate more recent changes in orca occurrence from earlier years.

Findings indicate that the resolution of this data is not high enough to significantly correlate the salmon measures with monthly orca occurrence relative to the orcas' year-round habitat, but it has documented a recent shift in their historical pattern. There is a higher occurrence of the orcas in the spring and a lower occurrence in the fall, as contrasted with an annually steady occurrence in the summer and winter. However, in 1997 there was a sharp increase in the fall occurrence of the orcas in Puget Sound, which is a significant departure from this trend, and may be indicative of food availability stress in this orca population.



## Microhabitat Use by Rocky Reef Fishes in Puget Sound

**Robert E. Pacunski and Wayne A. Palsson**

*Washington Department of Fish and Wildlife*

Scuba, video, and acoustic surveys have been conducted in Puget Sound, Washington State, since 1992. These surveys have identified major and minor habitat associations of principal reef fishes including copper rockfish (*Sebastes caurinus*), quillback rockfish (*S. maliger*), Puget Sound rockfish (*S. emphaeus*), kelp greenling (*Hexagrammos decagrammus*), and lingcod (*Ophiodon elongatus*). In particular, copper rockfish showed a high association with boulder fields and less usage of walls and rubble fields. Observed habitat associations may be in part the result of fishing and comparisons with patterns with fished areas and no-take refuges may help to identify the effects of fishing on habitat use by reef fishes.

## Severity and Magnitude of Puget Sound Coastal Bluff Landsliding, 1996–97

**Dr. Leonard Palmer**

*Portland State University*

Active landsliding during 1996–1997 was observed along approximately 20% of sampled sections of coastal bluffs in northern Puget Sound. Recent landsliding (within the last 3–5 years) was observed along about 30% of the bluffs. Thus, about half of the sampled bluffs demonstrated active landslide evidence within approximately the past five years. In 1996–97, five people died, about 2% of homes were destroyed and many others sustained extensive damage. About 16% of remaining homes on or below the bluffs appeared to be at severe risk by having no (less than 10 feet) set back from the bluff top or bluff toe. About 60% of the sampled coastal bluffs are now developed, providing opportunity for improved development guidelines for the remaining undeveloped 40% of coastal bluffs.

In this investigation, aerial reconnaissance photographic sampling of coastal bluff landslides in northern Puget Sound on April 1997 was done to obtain a comparative evaluation of the magnitude and severity of coastal bluff landsliding. The sample is based upon east-facing bluffs (exposed to sunlight during the flight) of Kitsap and Jefferson counties from Bainbridge Island northward to Marrowstone Island, and of Magnolia Bluff in Seattle. The landslide activity in sections of coastal bluffs ranged from 6% to 36% of the 10 coastal bluff sections. Most of the homes on the bluffs appeared to be constructed closer to the edge of the bluffs than a 45° slope extended from the base of slope.

Apparent causes of landsliding include glacial stratigraphic conditions, wave undercutting, concentrated and accelerated surface and underground drainage from above, uncontrolled land grading and vegetation changes, and triggering by natural seasonal storm events, especially those of greater than normal magnitude. The 1996–1997 storm was at least a 100-year event (USACE, 1997).

## **Trawl Survey Results in the Transboundary Waters of Washington and British Columbia**

**Wayne A. Palsson, James Beam, Suzanne Hoffman, and Paul Clarke**

*Washington Department of Fish and Wildlife*

Bottom-trawl surveys have been conducted in Washington since 1987, and in 1997, a synoptic survey was conducted in the transboundary waters of Washington and British Columbia. The surveys were designed to estimate numerical abundance of key benthic species, identify population trends, and quantify the impact of fisheries. The 1997 survey was also designed to describe the distribution of key commercial fishes that inhabit the Strait of Georgia but likely move between both sides of the international boundary.

Standard trawl-survey methodology was used to design the stratified systematic surveys. A 400-mesh Eastern Trawl was towed by a chartered fishing vessel. The bottom trawl is fitted with a codend net liner with a 1.25-inch mesh opening, and the trawl is towed at predetermined stations for 10 minutes. Trawl surveys were regionally based and at least 25 samples were taken each year. Five depth strata were designated as follows: 5–20 fathoms, 21–40 fms, 41–60 fms, 61–120 fms, and >120 fms.

Population trends will be evaluated as well as the effectiveness of survey design. The impacts of fishing will be discussed in relation to areas of heavy, little, or no commercial fishing.

## **Riverton Creek West Restoration Project: Partnership Approach for Habitat Restoration and Flood Control at an Urban Watershed**

**Ryan Partee**

*City of Tukwila*

**Ira Dunbar, Denis Bourcier**

*Boeing*

The Riverton Creek watershed drains approximately 430 acres and is located in Northwest Tukwila. The west tributary drains a small, forested area before crossing a major transportation corridor as it winds through the middle and lower watershed, which comprises residential and industrial areas. The east and west tributaries meet just upstream of the Duwamish estuary bridge at Route 599. The creek is subject to stormwater runoff originating from various land uses, including agricultural, residential, industrial, and transportation.

The objective of the current restoration project is to build on past efforts to combine revegetation and provision of in-stream habitat improvements into a multi-steward strategy that would increase fish habitat while reducing flooding potential at industrial operations adjacent to the creek. The stakeholders and users include the City of Tukwila, King County (KC), Tukwila Elementary School, WA Dept. of Fish and Wildlife, residents of the Riverton community in Tukwila, and Boeing Company employees. Additionally, the restoration parallels the Storm Water Pollution Prevention Plan BMP's for the Boeing facility as well as the watershed-wide plan for improvements currently being implemented by the City. Utilizing City of Tukwila as well as Boeing Company resources and volunteers, in addition to support provided to the city of Tukwila via a KC stream habitat improvement grant, the restoration project incorporates traditional revegetation methods with specific habitat improvements and physical barriers to sediment input to the stream. The resultant reductions in stream sediment loading and localized alterations have permitted the

yearly installation of a salmon egg-hatching incubator and yearly releases of salmon fry that are being raised at area elementary schools. Selective use of small sediment detention ponds and source control, combined with revegetation and in-stream habitat additions, have resulted in dramatic improvements in water quality and availability of habitat. This project provides an example of how an urban stream tributary can be upgraded and still meet flood control needs in a watershed that is subject to various contaminant and sediment loading sources.

## **Risk-Based Monitoring of Chemical Contaminants in an Intertidal Seep Zone**

***Gary A. Pascoe and Len Hayman***

*EA Engineering, Science and Technology, Inc.*

***Les Williams***

*Foster Wheeler Environmental, Inc.*

***Renee Wallis***

*U.S. Navy*

As part of a five-year monitoring program along the shore of Liberty Bay, metals and semi-volatile organic chemicals were measured in ground water, seeps, sediments downgradient of the seeps, and shellfish. Groundwater transport and discharge results in exposures of marine organisms and humans to groundwater contaminants, particularly in the intertidal zone where groundwater directly contacts marine sediments and shellfish. Consequently, the monitoring program was developed to: (1) document the effectiveness of natural processes on attenuation of chemical concentrations in groundwater; and (2) develop site-specific measures of chemical exposure that could not be accurately predicted in a risk assessment. Samples were collected from over a dozen wells screened in surficial groundwater, two downgradient seeps, and nine sediment and shellfish (littleneck clams) stations arranged as a grid in the intertidal and subtidal zones. Along the shoreline of the site, spatial trends in cadmium and chromium concentrations were apparent in seep water, sediments, and clam tissues. Concentrations of chromium, cadmium, and several other chemicals in sediment and shellfish tissue were elevated above reference (EAR) area concentrations. The EAR ratios decreased along the exposure pathway from groundwater to sediments to tissues. These results indicate that sediment and tissue sampling are effective monitoring end points of ecological risk and natural attenuation of contaminated groundwater discharge into the marine environment.

## **Contaminated Sediment Disposal, Development, and Application of Siting Criteria in Bellingham Bay**

**Clay Patmont and Tom Schadt**

*Anchor Environmental, L.L.C.*

**Tracey P. McKenzie**

*Pacific International Engineering*

**Mike Stoner**

*Port of Bellingham*

**Rachel Friedman-Thomas and Lucille Pebles**

*Washington Department of Ecology*

**John Anderson**

*Georgia-Pacific West, Inc.*

The objective of this paper is to present a two-part process used by the Bellingham Bay Demonstration Pilot Project Work Group to blend participating agencies/entities goals, policies, regulations, and objectives into a process that identifies and prioritizes disposal sites for contaminated sediments in Bellingham Bay. Part One used exclusionary, avoidance, and cost screening criteria, along with available GIS databases, to identify a long list of 70 potential upland, nearshore fill, and confined aquatic disposal sites. Part Two involved the development of disposal site evaluation criteria and scoring guidelines relative to Pilot Project goals, and application of these scoring guidelines to the long list of disposal sites. Application of the scoring guidelines to the long list of disposal sites will be presented, along with a description of how final contaminated sediment disposal site alternatives were identified by the Work Group. These final disposal alternatives will be more fully evaluated in a forthcoming Feasibility Study and SEPA/NEPA EIS.

## **The Biosolids Handshake**

**John Poppe**

*City of Bremerton*

The City of Bremerton constructed an 18-hole golf course in the 1960s. The demand for the facility provided the City an opportunity to expand the course in 1995–96 by adding another 18-hole course for public use.

Grade work and surface contouring began in the fall of 1995 and was completed early in 1996. The soil conditions were generally clay and sand with a predominance of fine sand as the final top mix. The fairways and greens were planted with grass seed from April through July 1996.

The sandy soil was very low in plant nutrients and had no organic content for water retention. Therefore, commercial fertilizer was used every two weeks as the nutrient source, with several water applications per day.

The anticipated growth (without biosolids) of the new turf prohibited course play until March 1997. The new course play schedule resulted in concern about the delayed time from the capital investment to the start of revenue by those playing the new course.

The City of Tacoma and the City of Bremerton have been developing the use of biosolids for various uses around Kitsap County for several years. This cooperation resulted in the City of Tacoma applying 361,000+ gallons at 5% total solids to 90% of the new Bremerton golf course.

As a result of the cooperative efforts of the Class A biosolids application, the new course opened on the Labor Day weekend of 1996. The revenue generated by the early opening is estimated to be \$300,000.

## **Depositional and Erosional Mechanisms and Rates in Elliott Bay from Geological, Geophysical, and Historical Hydrography Data**

**Kyle K Ren, Michael Hutnak, and Mark L. Holmes**

*University of Washington*

The objectives of this study were to determine the depositional and erosional environments in Elliott Bay, a Puget Sound embayment forming the Seattle waterfront, and to describe and quantify processes responsible for producing those environments. Hydrographic charts from 1935 and 1970, together with bathymetry profiles obtained in 1996 and 1997, were digitized and differenced to determine areas exhibiting significant changes in depth. Granulometric data for 500 previously collected bottom samples were analyzed to characterize depositional and erosional environments. Piston coring and reflection profiling were used to map seismic-stratigraphic units and examine subsurface stratigraphy. Paleobathymetric analysis shows the eastern marginal slopes of the Elliott Bay to be undergoing almost continual erosion, whereas the western slopes are characterized by depositional environments. The average net accumulation rate over the entire embayment was 0.6 cm/yr between 1935 and 1970. Episodic turbidity currents (~1/century) and submarine landslides have eroded into pelagically deposited sediment in outer Elliott Bay and along two inner submarine canyons. Bottom morphology and geometry of stratigraphic units suggest turbidity current velocities of 3–13 m/sec. The frequency and magnitude of turbidity currents and landslides suggest that care should be taken when choosing locations for sewer outfalls, submarine cables and pipelines, and dredge spoil disposal sites.

## **Toxic Response and Bioaccumulation in a Deposit-Feeding Polychaete—Relative Life-Stage and End-Point Sensitivity, and the Potential for Trophic Transfer**

**Casimir A. Rice**

*University of Washington*

**Gina M. Ylitalo, Barbara L. French, and Ed Casillas**

*Northwest Fisheries Science Center*

This study provides a comprehensive set of baseline toxicity data that characterizes critical life stage responses of an animal with a typical marine life history, in long-term sediment exposures over a wide range of toxicant concentrations. The opportunistic, deposit-feeding polychaete *Armandia brevis* was exposed for 60 days to sediments supplemented with each of the toxicants dieldrin, pp'DDE, Aroclor 1254, fluoranthene, cadmium, copper, lead, and mercury. Mortality and emergence from sediment (an avoidance response) were recorded daily, and growth and maturity were measured at 20, 40, and 60 days. To assess recruitment, cultured planktonic larvae were presented with the same sediments as the juveniles and adults. All life stages of *A. brevis* proved amenable to laboratory experimentation. For all toxicants, the overall pattern of end-point sensitivity was growth (most sensitive) > settlement > maturity > emergence > mortality (least sensitive). The general rank of toxicant toxicity was dieldrin (most toxic) > pp'DDE = Aroclor 1254 = fluoranthene > copper > cadmium > lead = mercury (least toxic). Regression relationships between sediment and whole-body concentrations of organic compounds were linear, with bioaccumulation factors ranging from approximately 15 to 25. Overall, these results give insights into how anthropogenic chemical contamination may affect benthic marine ecosystems through differential effects on various life-history parameters.

## **Puget Sound Intertidal Habitat Inventory: Vegetation Mapping**

***Rebecca Ritter and Allison Bailey***

*Washington State Department of Natural Resources*

Puget Sound's nearshore habitats are a natural resource of significant value. The region's rapidly growing population continues to push habitat issues to the forefront for resource decision makers. The Washington State Department of Natural Resources, as part of a project to monitor the nearshore environment through the Puget Sound Ambient Monitoring Program, has characterized intertidal and canopy-forming vegetation in Puget Sound. This poster summarizes the inventory method used, and discusses the impact of geospatial detail on subsequent applications. Eight intertidal vegetation types were classified using multispectral imagery: eelgrass, brown algae, kelp, green algae, mixed algae, salt marsh, spit and berm vegetation, and red algae. The vegetation types encompass most common macroscopic vegetation found along Puget Sound's shorelines. Ground data, collected during the growing season, were used to guide the classification, or for classification accuracy assessment.

Comprehensive management of these important resources is best addressed by appropriately accurate and detailed information. The intertidal vegetation inventory provides information on the following characteristics of a feature: type, location, distribution, areal extent, shape/boundary, size range, and fragmentation. This high-resolution (4 m) inventory with polygon representation of features allows for detailed analysis of vegetation beds over broad areas, adding an important dimension to applications that analyze spatial relationships.

## **Elevated Levels of PCBs, PCDDs and PCDFs in Harbour Seals (*Phoca vitulina*) and Killer Whales (*Orcinus orca*) Inhabiting the Strait of Georgia, British Columbia, Canada**

***P.S. Ross, M.G. Ikonomou, and R.F. Addison***

*Institute of Ocean Sciences*

***G.M. Ellis***

*Pacific Biological Station*

***L.G. Barrett-Lennard***

*University of British Columbia*

We carried out a study aimed at assessing the levels of the polychlorinated -biphenyl (PCB), -dibenzo-p-dioxin (PCDD), and -dibenzofuran (PCDF) chemicals in free-ranging harbor seals and killer whales in British Columbia, Canada. Blubber samples were obtained from 43 harbor seals from three different areas in the Strait of Georgia. Pneumatic darts were used to obtain blubber samples from six known-age free-ranging killer whales from a southern resident pod, animals known to frequent Strait of Georgia waters, as well as 24 northern residents. Congener-specific analysis of PCBs and PCDD/Fs was carried out using gas chromatography-high resolution mass spectrometry (GC-HRMS). Concentration-age relationships were generated for males and females of both species. We estimated that a 10-year-old male harbor seal has 294 ng/kg of 2,3,7,8-TCDD Toxic Equivalents (TEQ) and 21 mg/kg PCB; a 15-year-old female has 118 ng/kg TEQ and 8 mg/kg PCB; while a 22-year-old male killer whale has 893 ng/kg TEQ and 106 mg/kg PCB; a 45-year-old female has 139 ng/kg TEQ and 22 mg/kg PCB in blubber (lipid weight). The lower levels in females of both species reflected the loss of contaminants to their calves during pregnancy and

lactation. We estimate that 3.3 kg of PCBs are distributed among the 30,000 harbour seals and 6.2 kg are distributed among the 96 killer whales frequenting Strait of Georgia coastal waters. Results suggest that contaminant levels may be high enough in some of the marine mammals inhabiting this coastal region of Canada to affect reproduction, immune function, and endocrine function, and that the killer whale population may be at particular risk.

## **Application of Multiple-Bioassay Interpretation Index to Four Interpretive Frameworks**

***Bruce W. Rummel and Spyros P. Pavlou***  
*URS Greiner, Inc.*

Body of a multiple-bioassay index (MBI) has been developed to evaluate results from abstract sediment bioassays and to provide a metric for facilitating sediment quality assessment. The index integrates the results of different bioassay tests into a single value, which represents the cumulative contribution of each test. The index allows for the explicit derivation of threshold levels for no adverse effect, minor adverse effects, and adverse biological effects consistent with regulatory criteria. The MBI is compared to four existing interpretive methods: Washington Sediment Management Standards, Puget Sound Dredged Disposal Analysis (PSDDA), USEPA/USACE negative control response method, and the reference envelope method of the California State Water Resources Board.

## **Caged-Mussel Pilot Study at the Port Alice Pulp Mill on Vancouver Island, B.C.**

***Michael H. Salazar***  
*Applied Biomonitoring*

***Sandra M. Salazar***  
*EVS Consultants*

An *in-situ* caged mussel pilot study was conducted to evaluate this approach as part of Environmental Effects Monitoring (EEM) at Canadian pulp and paper mills. The objective of the pilot study was to test the feasibility, scientific value, and applicability of using caged bivalves as a tool for EEM. Effects endpoints included survival, growth, percent water, and percent lipids. Exposure endpoints included mussel tissue chemistry and chemical analysis of lipid bags (semi-permeable membrane devices; SPMDs). To provide the option of including this methodology as part of Cycle 2 of EEM, the pilot study was conducted from August–October, 1997 at the Port Alice Mill pulp mill, Vancouver Island, B.C. Planning has been open to industry, government, and consultants. Representatives from each group observed and participated in the actual sorting, measurement, and deployment process. The scope of work included an element of technology transfer and the project was viewed as a combined Pilot Study-Workshop. The study will be evaluated based on previously established criteria such as: 1) scientifically defensible; 2) cost-effective; and 3) well-defined decision points. A significant relationship was found between proximity to the mill effluent diffuser and reduced mussel growth. Results show potential applications for monitoring effluents in Puget Sound.

## **Survival and Growth of Caged Mussels at 70-Meters Depth in Port Valdez, Alaska**

**Michael H. Salazar**

*Applied Biomonitoring*

**Sandra M. Salazar**

*EVS Consultants*

An *in-situ* field study was conducted to evaluate the feasibility and scientific value of using caged mussels as a monitoring tool to characterize chemical exposure and biological effects associated with the Ballast Water Treatment Facility (BWTF) effluent being discharged into Port Valdez, Alaska. A tiered approach was used; mussel survival and growth in Tier 1; chemical analysis of mussel tissues in Tier 2. Caged mussels (*Mytilus trossulus*) were transplanted at seven sites in the vicinity of the BWTF diffuser at a depth near 70 meters. Three hundred mussels were deployed for 56 days at each station; cages with individual compartments were used to facilitate measurement of individuals at the beginning and end of the test. There were no statistically significant differences in either weights or lengths by station at the beginning of the test. Mean survival of mussels was 97% and there were small increases in mean length (5%) and weight (7%). Growth results were similar to other mussel transplants in southeast Alaska and natural populations of intertidal mussels in the vicinity of the BWTF. The pilot study demonstrated that mussels transplanted to depths near 70 meters in Port Valdez will survive and grow so chemical analysis will proceed.

## **Long-term Trends in Willapa Bay, Washington from 26 Years of Oceanographic Observation: Effects of El Niño and Other Natural Cycles**

**Rebecca Schudlich**

*University of Washington*

**Carol J. Falkenhayn, Casey Clishe, and Jan Newton**

*Washington Department of Ecology*

This study characterizes the natural forcing and responses of the physical-biological dynamics of Willapa Bay, a large estuary in southwest Washington. Data from the Washington State Department of Ecology's long-term Marine Waters Monitoring program (MWM) supplies 26 years (1973–present) of quasi-monthly measurements of temperature, salinity, water clarity, nutrients, chlorophyll-a, and fecal coliform bacteria. Recent data (1997–present) from an EPA-funded study of Willapa Bay conducted by the Washington State Department of Ecology provides additional measurements of temperature, salinity, water clarity, and chlorophyll-a concentrations at a much higher time resolution (15-minute). The MWM data provide a long-term perspective on the effect of seasonal cycles and several El Niño events on the dynamics of Willapa Bay. The EPA data capture the unfolding 1997–98 El Niño event, while resolving tidal cycles, weather, and runoff events. Fecal coliform bacteria levels are highest near river mouths and during rain-dominated seasons, as expected. El Niño events have had a variety of effects on Willapa Bay. The present El Niño is significantly warmer (by 2–3 °C) than any of the other seven El Niño events measured since 1973; its continuing effects on Willapa Bay are still being measured.



## Asian Pacific American Seafood Consumption Study

**Ruth Sechena and Richard A. Fenske**

*University of Washington*

**Connie Y. Nakano**

*Refugee Federation Service Center*

**Shiquan Liao**

*StatPro Consultants*

**Nayak Polisaar**

*The Mountain-Whisper-Light Statistical Consulting*

**Objective:** Data gaps exist in the characterization of seafood acquisition and consumption habits among Asian Pacific Americans (APA) because they traditionally consume different types and parts of seafood than the general United States public. This study documents APA seafood acquisition and consumption habits within 10 ethnic groups (Cambodian, Chinese, Filipino, Korean, Hmong, Japanese, Lao, Mien, Samoan, and Vietnamese) in King County, Washington.

**General Methodology:** To address these data gaps a two-year EPA Environmental Justice Community/University Partnership Grant was awarded to the Refugee Federation Service Center (RFSC) and the University of Washington, NIEHS Center for Ecogenetics and Environmental Health, Community Outreach and Education Program. A questionnaire was developed to characterize seafood acquisition, preparation and consumption. Study participants were randomly selected from volunteer lists, as well as community and church rosters. Bilingual surveyors used plaster seafood models to elicit more accurate seafood meal size estimates, and have completed a total of 200 survey interviews.

**Results:** Preliminary results were expected by February 1998.

**Significant Conclusions:** Pending.

**Practical Applications:** This study will provide valuable information about APA seafood consumption patterns in terms of types of seafood consumed, quantitative meal size estimates, and preparation practices.

## Non-ionic Surfactants in Marine Sediments of the Strait of Georgia

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*Institute of Ocean Sciences, Canada*

Toxic to aquatic organisms and suspected endocrine disruptive compounds, non-ionic surfactants nonylphenol and its polyethoxylates (NPnEO, n = 1–19) are being phased out in Europe. However, so far no data of NPEOs are available in North American marine environment. Using liquid chromatography coupled to electrospray ionization mass spectrometry, we developed a highly sensitive quantitative method to analyze NPEO concentrations in marine sediments. Five gravity sediment cores and 21 grab samples collected from Strait of Georgia were assayed for NPEO concentrations. NPEO oligomers with up to 19 ethoxy units were found in Strait of Georgia sediments at concentrations ranging from 10 to 960 ng/g (dry weight basis). The application of Principal Component Analysis on the NPEO data set shows a remarkably clear separation between the coastal and non-coastal areas. The significant result from the new soft-ionization MS analytical method—that the metabolites of the longer polyethoxy-chain nonionic surfactant are persistent in marine sediments—is contrary to previous conclusions that only NP<sub>1</sub>EO and NP<sub>2</sub>EO

persist in the environment. The results of this work also suggest that a NPEO concentration mapping in the Puget Sound Strait is necessary to study the mobilization and biodegradation of NPEOs in sediments and to assess the potential environmental impact of NPEOs.

## **Methods for Analysis of Triad Data**

***Alice Shelly and Lorraine Read***

*EVS Environment Consultants, Inc.*

The Triad approach to the measurement of environmental contamination generates multiple endpoints from three (or more) categories. A sample Triad data set might contain synoptic information collected on sediment chemistry data for a suite of chemicals, laboratory toxicity data for several sediment bioassays, and *in-situ* observations of the benthic community. The objective of the triad analysis is to identify any relationships present between the different legs of the Triad, and to interpret the risk level of individual sites based on the weight of evidence conveyed in the synoptic measures of the Triad data set. Typically, each of the endpoints are subject to different sources of variability and the relationships between the legs of the Triad are generally not very clear making interpretation difficult. We present a multi-step process for aggregating the information from all endpoints to provide a relative framework for interpreting stations based on the weight of evidence, and an absolute framework for distinguishing between individual stations. We use exploratory analyses to help select the individual endpoints; a randomization technique to indicate which stations are uniformly dirty, uniformly clean, or indeterminate; and multivariate technique to display the distance between stations. We present the results for a Triad analysis performed on data collected from a metals-contaminated aquatic site.

## **Bioaccumulation of Hydrophobic Organic Chemicals by Aquatic Biota with Low Lipid Content**

***Burt Shepard***

*URS Greiner*

Equilibrium partitioning models are commonly used to predict organic chemical concentrations in both sediment and aquatic biota from the chemical concentration in water. For sediments, it is recognized that the partitioning relationship, and, thus, the predictive power of the equilibrium-partitioning model begins to break down at sediment organic carbon concentrations lower than 0.2–0.5% organic carbon. There is little if any information regarding the predictive power of the equilibrium-partitioning model for biota with a low lipid content. Partitioning of organic chemicals between sediment and a sea cucumber (*Parastichopus californicus*) with a lipid content less than 0.2% has been measured at several locations in Puget Sound. The measured sediment concentrations of organic chemicals have been used in an equilibrium-partitioning model to predict the chemical concentrations in sea cucumbers, which were then compared to the measured residues in the field collected animals. The model predictions in all cases were within a factor of 10 of the measured residues, and usually within a factor of four of the measured residues. Although the model correctly gives order of magnitude estimates of bioaccumulation in sea cucumbers, the model predictions are more accurate for animals with a higher lipid content.

## **Modeling of Propwash Effects on Sediment Capping Material**

**Vladimir Shepsis and David Simpson, P.E.**  
*Pacific International Engineering PLLC*

Velocity produced by a ship's propellers can be a significant agent in dispersing bottom sediment under particular combinations of water depth, propeller speed, and details of the propeller itself. This paper reports recent studies in Puget Sound that have investigated applicability of equations describing propwash velocity to specific water depths and propulsion systems that define conditions near certain ferry docks of the Washington State Department of Transportation. Predicting disturbance of bottom sediment requires accurate knowledge of water velocities experienced near the sediment surface. A model was developed that incorporated recent research on propeller-induced velocity field, and that included certain calibration constants relating to the radial spread of the velocity jet behind the propulsion system. Field measurements were then made to evaluate the constants and verify the model. The result of this effort is a tool that has applicability in predicting the dispersion of sediment, contaminated or otherwise; in predicting the zone in which the disturbance would take place; or in determining the depth of scour that would likely occur in a sediment cap; or in defining the sediment size of the capping material that would resist scour under given vessel-operating conditions.

## **Plasma Vitamin A as a Biomarker of Contaminant-Related Toxicity in Free-Ranging Harbor Seals (*Phoca vitulina*)**

**Wendy Simms**  
*Institute of Ocean Sciences and University of Victoria*

**Peter S. Ross and Michael G. Ikonomou**  
*Institute of Ocean Sciences*

Captive harbor seals fed herring from polychlorinated biphenyl (PCB)-contaminated waters have exhibited reduced levels of plasma vitamin A, partly as a result of the physiological disruption of the transport mechanism of this essential nutrient. Contamination of the marine environment with PCBs has resulted in the accumulation of high levels of these fat-soluble chemicals in harbor seals and other top predators. As part of an ongoing ecotoxicological study, we are examining plasma retinoid concentrations as an indicator of contaminant-related toxicity in healthy, free-ranging, Pacific Northwest harbor seals. In a preliminary effort, we live-captured twelve 3–4 week-old harbor seal pups in the Boundary Bay area of southwestern British Columbia. Heparinized blood samples were collected from the extradural vein of each seal, stored at 4 °C in the dark until centrifugation, and plasma was cryopreserved at –80 °C until analysis. Existing methods were adapted to extract vitamin A from plasma samples and to quantify it using reversed-phase high-performance liquid chromatography (HPLC). Retinol concentrations for the 12 seals averaged 378 µg/L ±34.8 (range 210 to 568 µg/L), and replicates were consistently within 6% of each other. Having established these techniques, we will be monitoring the retinoid disrupting effects of contaminants on harbor seals at several sites in BC and Washington.

## **Effects Of Contaminants on Reproductive Parameters of Male English Sole (*Pleuronectes vetulus*) From Puget Sound, WA**

***Sean Y. Sol, Brian D. Bill, Lyndal L. Johnson, and Tracy K. Collier***  
*National Oceanic and Atmospheric Administration*

Effects of contaminant exposure on gonadal development in adult male English sole (*Pleuronectes vetulus*) from Puget Sound, WA, were investigated. Maturing males were collected from two urban areas (Eagle Harbor and Hylebos Waterway) containing high levels of sediment PAHs (polycyclic aromatic hydrocarbons) and PCBs (polychlorinated biphenyls), and two moderately contaminated non-urban sites (Colvos Passage and Pilot Point). Reproductive parameters including gonadosomatic index (GSI) and the plasma reproductive steroid, 11-ketotestosterone (a steroid involved in spermatogenesis), were compared to levels of contaminant exposure measured as biliary fluorescent aromatic compounds (FACs). Preliminary results showed that fish collected from urban areas had elevated levels of biliary FACs compared to fish collected from non-urban areas. No significant differences in reproductive parameters (GSI and plasma 11-ketotestosterone levels) were observed, and the proportion of maturing animals was similar between fish collected from urban and non-urban areas. Nevertheless, a few fish with high levels of biliary FACs had reduced GSI and plasma 11-ketotestosterone levels. In contrast to female sole, which have been shown to undergo reproductive impairment when exposed to these contaminants, males seem to be relatively resistant to contaminant exposure. However, sufficiently high exposure may have the potential to reduce gonadal development.

## **Merging Industrial SWPPP BMP's with P3 Initiatives: Solid Waste Compactor Pad and Decant Station**

***Ralph W. Squires, Dave Logsdon, and Denis Bourcier***  
*Boeing*

Facilities improvements commonly address the aspects of both Industrial Storm Water Pollution Prevention Plan as well as WDOE-controlled Pollution Prevention Plans. The current project, which is the subject of this paper, provides both 1) a work area for compacting, weighing and separating solid waste; and 2) a decant station for street sweeper, storm water catch-basin, and oil/water separator clean-out waste. The combination of these activities at the solid waste pad result in a substantial waste reduction based on its in-ground aqueous waste separation capabilities, as well as the ability to segregate, weigh, and compact solid-waste materials in an enclosed area with stormwater pollution control.

Our previous research has characterized oil/water separator and catch-basin waste at two facilities such that the physical and chemical properties of the waste allow for separation of solids, oil fraction and aqueous component using simple solids settling and oil flotation designs. The system produces effluent concentrations of FOG, metals, and solids that are well below POTW criteria. A total reduction of over 700,000 pounds of hazardous waste at four Boeing facilities was realized, the installation of an in-ground oil/water separator will streamline the current process. The multiple use of the pad for solid waste activities provides the needed control and removal of debris which otherwise might pose a stormwater pollution risk, while at the same time providing the protected space for solid waste segregation and weighing.

## **Accumulation of Tributyltin (TBT) in Invertebrates and Fish from the Duwamish Estuary and Non-Urban Reference Areas in Puget Sound, WA**

**John Strand**

*King County Water and Land Resources Division*

**Sandie O'Neill and James West**

*Washington Department of Fish and Wildlife*

**Scott Mickelson, Diane McElhany, Kevin Li, and Tom Georgianna**

*King County Environmental Lab*

Concentrations of TBT in invertebrates and fish were monitored by King County and the Washington Department of Fish and Wildlife in support of ecological and human health risk assessments of combined sewer overflows in the Duwamish River and Elliott Bay. Species monitored included English sole (*Pleuronectes vetulus*), quillback rockfish (*Sebastes maliger*), Dungeness crab (*Cancer magister*), bay mussel (*Mytilus trossulus*), and intertidal invertebrates, mostly amphipods (*Traskorchestia traskiana*).

Concentrations (wet weight) of TBT were highest in invertebrates and fish from the Duwamish River and Elliott Bay, and significantly lower in organisms from reference areas. TBT concentrations in sediments were also higher in the Duwamish River and Elliott Bay than in reference areas. Highest concentrations of TBT were found in the soft bodies of bay mussels (177.8 µg/kg) and crabs (81.9 µg/kg) from the Duwamish River and Elliott Bay. Concentrations of TBT in fillets of the longer-lived quillback rockfish from Elliott Bay (38.8 to 50.2 µg/kg) were significantly higher than concentrations of TBT in fillets of English sole from Elliott Bay (3.8 to 5.6 µg/kg). Concentrations of TBT in intertidal invertebrates (whole animal) from Kellogg Island in the Duwamish River ranged between 17.6 and 36 µg/kg, essentially the same range of concentrations measured in sediments at Kellogg Island.

## **Developing an Alternative Watershed Management Approach: Preliminary Results of Modeling and Measurements for Sinclair Inlet**

**Steven R. Swanson**

*Puget Sound Naval Shipyard*

**Kenneth Richter and P. F. Wang**

*SSC - San Diego*

Puget Sound Naval Shipyard has proposed a project to EPA (through the Project XL framework) to create an integrated watershed management approach for Sinclair Inlet based on solid scientific research. This will involve comprehensive monitoring, computer modeling of the inlet and watershed, and an ecological risk assessment. This project will also incorporate extensive stakeholder involvement. Preliminary research has included three-dimensional computer modeling of Sinclair Inlet and initial real-time and ambient measurements of water quality and characteristics. This included metals, salinity, temperature, dissolved oxygen, currents, and others. This paper will present the early modeling results, data from measurements, and correlations between the model and data. The inlet hydrodynamics were shown to be dominated by tidal and wind forces, and demonstrated three-dimensional characteristics. This model will eventually be used to predict

contaminant fate and transport and may be linked to surface water models to predict contaminant loading. Additional monitoring of the watershed will be necessary over a long time scale to assess seasonal variations. The results of this project will be used to determine realistic TMDL's based on actual ecological impact and risk assessment, as well as developing an innovative, alternative regulatory approach to managing the entire watershed based on community goals.

## **A Large Outbreak of Vibriosis in Washington State, 1997**

***Patti Waller, Ned Therien, and Maryanne Guichard***

*Washington Department of Health*

*Vibrio parahaemolyticus* is a naturally occurring bacterial pathogen that increases in marine waters and sediments during warm summer months. Large numbers of the organism in seafood can cause illness primarily characterized by diarrhea.

In Washington the number of confirmed cases of vibriosis has ranged between two and 36 cases per year since it became a reportable illness in 1987. In 1997 there was a marked increase in the number of vibriosis cases in the state, with a total of 57 laboratory-confirmed cases and 19 suspect cases reported to the Washington State Department of Health (WDOH). Oysters were identified as the most likely vehicle of transmission in 61 cases (89%), with 55 ill persons consuming them raw. Most cases (62) occurred in late July and August. California, Oregon, and particularly British Columbia had similarly high numbers of vibriosis cases reported during the same period.

The WDOH, along with the commercial shellfish industry, took several actions, including stricter shellfish handling procedures, voluntary closure of oyster beds, mandatory closure of some oyster beds, and issuing news releases advising consumers to eat only thoroughly cooked shellfish products. Results of environmental sampling during the outbreak showed levels of the organism below the regulatory action level. This suggests the action level should be reevaluated.

## **Use of a Flux Chamber to Assess Groundwater Recharge into a Tidally Influenced Water Body, Thea Foss Waterway, Tacoma, WA**

***Birgitta Willix***

*Hart Crowser, Inc*

The flux chamber was designed to measure average groundwater flow into a surface water body and to collect time-averaged samples for chemical analyses. The design was based on David R. Lee's device and consists of an initially deflated plastic bag attached to a stainless-steel cone partially inserted in the sediments. Several modifications to Lee's design were added to ensure stability in a tidally influenced environment. Five chambers were placed in the Thea Foss Waterway in Tacoma. They collected water at rates varying between 0.02 and 1.57 gallons per day per square foot, showing significant variability in the groundwater flow. Salinity measured in the samples varied from 0 to 27 ppt. Groundwater in the Thea Foss Waterway area has displayed similar variability in salinity. Preliminary analytical data (analytical results have not been received from the laboratory to date) will be presented and its use in the evaluation of alternatives for remediation of contaminated sediments discussed.

## **Sediment Quality Changing At Cleanup Site along Seattle Waterfront**

***Dean Wilson and Pat Romberg***

*King County Water and Land Resources Division*

In 1992 a layer of clean sand was placed over 4.5 acres to isolate or cap contaminated bottom sediments located north of the Coleman Ferry Dock and offshore of Piers 53–55. Repeated monitoring four years after cap placement show many changes in the surface sediments, but that the sand is still isolating underlying contaminated sediments.

Surface samples taken in 1996 showed that previously elevated levels of PAHs have decreased, while two new chemicals were detected that have not been previously found along the waterfront. The source of 4-methylphenol and phenol has not been determined, but both chemicals are used in a variety of products. Benthic taxonomy samples show the site is repopulated, but the benthic community has become more like the pre-cap community. This change may be partly linked to a greater percentage of fine-grained sediments in the remediation area.

## **Washington Department of Fish and Wildlife's Wetland Inventory Project**

***Robin Woodin***

*WDFW Habitat Program*

Washington Department of Fish and Wildlife (WDFW) is addressing its role of wetland stewardship through first conducting a detailed wetland inventory of all agency lands. The information collected includes maps, classifications, noxious weed occurrence and extents, restoration and enhancement options, and adjacent land uses. Designed to benefit other potential users of this wetland information, the database includes a complete digitally mapped component (GIS coverage). The project began with the type of agency land having the majority of acres, the “Wildlife Areas,” which comprise more than 700,00 acres statewide. Wildlife Areas have been purchased or brought under management through formal agreement for the purpose of managing for target wildlife or fish species. Consequently, the proportion of wetlands on these WDFW lands is four times greater than the total land base of Washington State.

